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# BIOLOGICAL BULLETIN

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## ENTOMOSTRACA AND LIFE ZONES.

### A STUDY OF DISTRIBUTION IN THE COLORADO ROCKIES.

GIDEON S. DODDS,  
WEST VIRGINIA UNIVERSITY.

#### I. THE REGION COVERED.

In a former paper ('17) I described the altitudinal distribution of the 71 species of Entomostraca known to occur within the limits of the state of Colorado. Fifty-five of these species are from my own collections made in a definite attempt to gather a reasonable amount of information about the nature of the entomostracan fauna at different elevations in this part of the Rocky Mountains. The material included 280 vials of plankton from 124 lakes and ponds at elevations ranging from 4,100 to 12,188 feet above sea level. By far the greater number of these collections are from an area covering adjacent parts of the counties of Boulder, Jefferson, Gilpin, Clear Creek, and Grand, and includes, within a distance of 25 miles, portions of all the life zones from the Upper Sonoran to the Arctic-Alpine. A full description of the topography and climate of this region is included in my former paper. In addition to my own collections from this region, together with a few from other parts of the plains of the state, I have made use of all available records of species collected by others within the state.

The state of Colorado affords an area for study which is not wholly an arbitrary or unnatural one. Its higher portions include the greatest elevations of the Rocky Mountains, with their southern extension of climatic and biotic characters from the north, and its lower portions are typical of the arid and hot conditions of the southwestern portion of the United States, while its position astride the Continental Divide makes it the meeting place of

eastern and western species. Its biota is accordingly composed of a mixture of northern and southern, of eastern and western forms. Reports on plants, birds, and mammals testify to the richness and variety of life here where so diverse conditions are condensed within a restricted area.

In my former paper I referred the Entomostraca of my list to

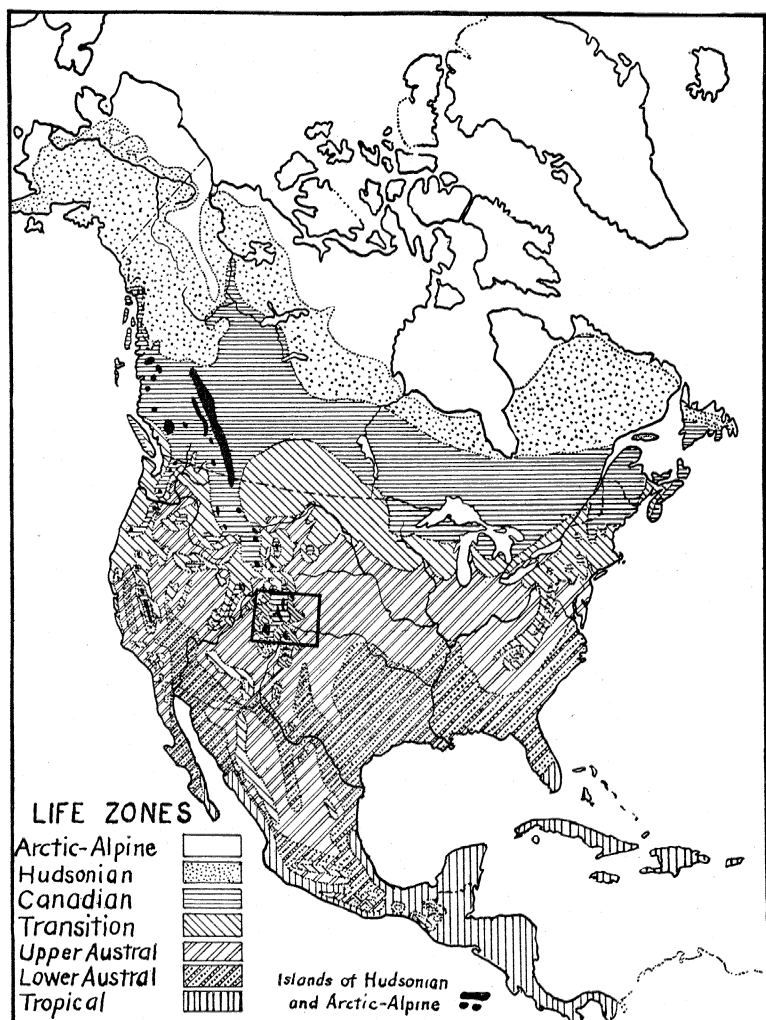


FIG. 1. Life-zone map of North America with outline of state of Colorado drawn in. After Merriam, etc., from A. O. U. Check-list of North American Birds, 3d edition (revised), 1910.

the modification of Schimper's zones adopted by Ramaley in his studies of the vegetation of the area. It seems desirable, however, to tie this fauna to the larger life zones which apply throughout the continent as a whole and which have been mapped out by Merriam and are now made use of by a considerable number of those interested in problems of distribution. Figure 1 shows how these zones are distributed over the continent. Of special interest are the southward extensions and islands of the northern zones over the higher areas, as in the Appalachians, Rockies, and Sierras. The outline of Colorado, indicated by the

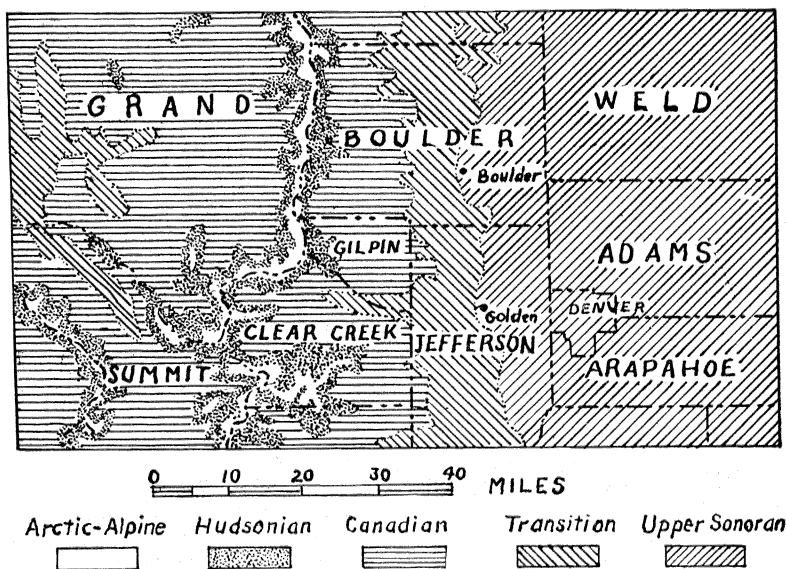


FIG. 2. Life-zone map of the portion of Colorado where most of the writer's collections were made. Shows close approach up Upper Sonoran and Arctic-Alpine Zones and narrowness of other zones in this region. After Cary.

black rectangle, shows the position of the area under consideration with reference to one of these southward extensions. Cary ('11) publishes a more detailed life-zone map of the state, a small portion of which is reproduced in Fig. 2. This includes the area from which most of my records come and shows that within a few miles are met Upper Sonoran, Transition, Canadian, Hudsonian, and Arctic-Alpine Zones.

The approximate altitudinal limits and outstanding floral characters of these zones in this part of the state as given by Cary and verified by my own observations, are as follows:

1. *Upper Sonoran* (arid, western portion of Upper Austral): Western edge of the Great Plains as far as the base of the foothills (about 5,300 feet). Grassland with deciduous trees along watercourses only.

2. *Transition*: The foothill region up to about 8,000 feet: Characterized by an open growth of rock pine (*Pinus scopulorum*).

3. *Canadian*: Includes the intermediate mountain elevations up to about 10,500 feet. Lower portion characterized by a dense growth of lodge-pole pine (*Pinus murrayana*) which gives place at about 10,000 feet to a close forest of Engelmann spruce (*Picea engelmanni*) and balsam fir (*Abies lasiocarpa*).

4. *Hudsonian*: A rather narrow strip characterized by a dwarfing of the spruces and firs of the Canadian Zone and bounded above by timberline, a sharply defined but jagged division line occurring roughly at about 11,000 feet.

5. *Arctic-Alpine*: An area without trees or woody plants except some scrub willows. Huge snowdrifts last far into the summer or do not entirely melt. Summer temperatures are accordingly low and the season is short.

## II. THE SPECIES OF ENTOMOSTRACA.

Table I. gives the list of species recorded for this area, and indicates for each the zones within which it has been collected. Of course it must be recognized that to make these data of final importance, very much more extensive collections are needed. It is apparent, however, that even the incomplete records here presented are sufficient to bring out facts of interest. The records for the more abundant species are sufficient to give wholly dependable results while the scattered records of the rarer ones are accurate as far as they go, but leave deficiencies and blanks to be filled by subsequent collections.

I have also included in Table I. the zones inhabited by each of these species throughout the Continent as a whole. These data are in many cases incomplete and in others uncertain because I have not had access to literature where I might find detailed ac-

TABLE I.

SHOWS ZONAL DISTRIBUTION AND GENERAL RANGE OF EACH SPECIES RECORDED FROM COLORADO.

Zones occupied in Colorado, as indicated by local collections, are designated in the upper line: LA, UA, T, etc. The probable distribution among the life zones throughout the continent of North America is indicated in the lower line: la, ua, t, etc. The Tropical Zone is omitted because of difficulty of determining with certainty which species enter it. A brief statement of general range is given in the last column. Records in parenthesis are for species not in my collections.

Species.	Number of Lakes	Zones.						Range.
		Lower Austral.	Upper Austral.	Transition.	Canadian.	Hudsonian.	Arctic-Alpine.	
<i>Branchinecta coloradensis</i> Packard . . . . .	7		UA				AA	Colorado .
<i>Diaptomus shoshone</i> Forbes . . . . .	39				C	H	AA	Colo., Yellowstone.
<i>D. arapahoensis</i> Dodds . . . . .	4						AA	Colo.
<i>D. coloradensis</i> Marsh . . . . .	29			T	C	H	AA	Colo.
<i>D. lintoni</i> Forbes . . . . .	2				C			Colo., Yellowstone.
<i>D. judayi</i> Marsh . . . . .					(C)			Colo.
<i>D. nudus</i> Marsh . . . . .	7			T	C	H		Colo.
<i>D. leptopus</i> var. <i>piscinae</i> Forbes . . . . .	27			T	C	H		Colo., Mont., Alberta, Manitoba.
<i>Macrothrix montana</i> Birge . . . . .				t	c	(H?)		Rockies and Sierras.
<i>Limnetis gouldii</i> Baird . . . . .	2		ua	T	C	h		Ill., New England, Quebec.
<i>Latona setifera</i> (O. F. M.) . . . . .	1			t	c			Northern U. S. and Europe (rare).
<i>Holopedium gibberum</i> Zaddach . . . . .	11			t	C	H	aa	Yellowstone, Sierras North U. S. and Europe, Newfoundland, Greenland, Iceland, Alps.
<i>Eurycerus lamellatus</i> (O.F.M.) . . . . .	10			T	C	H	aa	Yellowstone, Sierras, North U. S. and Europe, Iceland.
<i>Acroperus harpae</i> Baird . . . . .	12			T	C	H		Yellowstone, Sierras, North U. S. and Europe.
<i>Depanothrix dentata</i> (Euren) . . . . .	2			t	C			Me., Mich., Wis., Europe.
<i>Camplocercus rectirostris</i> Schoedler . . . . .	2			?	C	?		Sierras, U. S., Europe.
<i>Pleuroxus procurvatus</i> Birge . . . . .	5			T	C			Northern U. S.
<i>Alonella exigua</i> (Lilljeborg) . . . . .	1			t	C			Me., Mich., Wis., Europe.

TABLE I.—*Continued.*

Species.	Number of Lakes.	Zones.						Range.
		Lower Austral.	Upper Austral.	Transition.	Canadian.	Hudsonian.	Arctic-Alpine.	
<i>A. excisa</i> (Fischer) . . . . .	2		ua	T t	c	h	?	U. S., Europe, Greenland.
<i>Canthocamptus staphylinoides</i> Pearse . . . . .	4		ua		C	H	AA	Nebraska.
<i>Streblocerus serricaudatus</i> (Fischer) . . . . .	1	la	ua	t	c	?		La. to Wis., Norway, Sweden, Europe in general.
<i>Macrothrix hirsuticornis</i> N. & B. . . . .	11	la	ua	T t	C c	H h	AA aa	Maine to Colo. Spitzbergen to north Africa.
<i>Alona affinis</i> (Leydig) . . . . .	15	la	ua	T t	C c	H h	AA aa	America and Europe from north to south.
<i>Alona guttata</i> Sars . . . . .	4	?	ua	T t	C c	?		Wide spread in America and Europe.
<i>A. rectangula</i> Sars . . . . .	22		ua	T t	C c	H h	AA aa	Wide spread in America and Europe, Pribilof Ids.
<i>Daphnia longispina</i> O.F.M. . . . .	48	?	ua	T t	C c	H h	?	Cosmopolitan with many varieties.
<i>Daphnia pulex</i> DeGeer . . . . .	48	la	ua	T t	C c	H h	AA aa	Cosmopolitan with many varieties.
<i>D. hyalina</i> Leydig . . . . .	1	?	ua	T t	C c	h	?	Wide spread in Old and New Worlds.
<i>D. psittacea</i> Baird . . . . .	6	la	ua	T t	c	h	aa	U. S., Greenland to Algiers.
<i>Ceriodaphnia reticulata</i> Jurine . . . . .	22	la	ua	T t	C c	H h	AA aa	Cosmopolitan.
<i>C. pulchella</i> Sars . . . . .		la	ua	t	(C) c	h	?	Cosmopolitan.
<i>Chydorus sphaericus</i> (O.F.M.) . . . . .	71	la	ua	T t	T t	H h	AA aa	Cosmopolitan.
<i>Cyclops albidus</i> Jurine . . . . .	16	la	ua	T t	C c	H h	AA aa	Cosmopolitan.
<i>C. bicuspidatus</i> Claus . . . . .	38	la	ua	T t	C c	H h	AA aa	Northern portions of America and Europe.
<i>C. serrulatus</i> Fischer . . . . .	30	la	ua	T t	C c	H h	AA aa	Cosmopolitan.
<i>C. viridis</i> Jurine . . . . .	45	la	ua	T t	C c	H h	AA aa	Cosmopolitan.
<i>Graptoleberis testudinaria</i> (Fischer) . . . . .	7	la	ua	T t	C c	H h	aa	U. S. and Europe.
<i>Simocephalus serrulatus</i> (Koch) . . . . .		la	a	t	c	h	?	Greenland.
<i>S. vetulus</i> (O.F.M.) . . . . .	26	la	ua	T t	C c	H h	?	Cosmopolitan.
<i>Scapholeberis mucronata</i> (O.F.M.) . . . . .	14	la	ua	T t	C c	h	aa	Yellowstone, Sierras, Greenland. Arctic to tropics.

TABLE I.—*Continued.*

Species.	Number of Lakes	Zones.						Range.
		Lower Austral.	Upper Austral.	Transition.	Canadian.	Hudsonian.	Arctic-Alpine.	
<i>Bosmina longirostris</i> (O.F.M.).....	3	la	UA ua	t	c	h	?	Yellowstone, Sierras. America and Europe from north to south.
<i>Canthocamptus minutis</i> Claus.....	1	la	(UA) ua	t	C c	h	?	Wide spread in America and Europe.
<i>Dunhevedia crassa</i> King	3	la	ua	T t	C c			La. to New England and Wis. Europe, Australia.
<i>Streptocephalus coloradensis</i> Dodds.....	4		UA	T	T			Colorado.
<i>Lepidurus bilobatus</i> Packard.....				(T)				Colorado.
<i>Estheria mexicana</i> Claus		la	(UA) ua	t	c			Lake Winnipeg to Mexico; Ohio to Rocky Mts.
<i>Diaptomus signicauda</i> Lilljeborg.....				(T) t	c			Colo., Sierras.
<i>D. sicilis</i> Forbes.....			(UA) ua	t	c			Neb., Wis., Yellowstone, Muskoka Lakes, Great Lakes.
<i>Pleuroxus aduncus</i> Jurine.....	1	la	UA ua	t	c	?		Colo., Calif. Northern Europe to Algiers.
<i>P. denticulatus</i> Birge...	3	la	UA ua	t				All parts of U. S.
<i>Leydigia quadrangularis</i> (Leydig).....	1	?	UA ua	?				U. S. and Europe.
<i>Kurzia latissima</i> (Kurz)		?	(UA) ua	?				U. S. and Europe.
<i>Moina brachiata</i> (Jurine)	7	la	UA ua	t				Wis. and southward. Europe to Egypt.
<i>Cyclops ater</i> Herrick...		la	(UA) ua	t				Minn. and Mich. to Alabama.
<i>M. affinis</i> Birge.....		la	(UA) ua	t				Wis. to La.
<i>Diaptomus pallidus</i> Herrick.....	1	la	UA ua	t				Wis. to La.
<i>D. siciloides</i> Lilljeborg.	2	la	UA ua	t				Wis. to Texas and Calif. (L. Tulare).
<i>D. claviceps</i> Schacht...	2		UA ua					Colo., Iowa, Neb.
<i>D. albuquerquensis</i> Herrick.....	1	la	UA ua					Colo., N. M., Mexico City.
<i>Marshallia albuquerquensis</i> Herrick.....	1	?	UA ?					Colo. and (N. Mex. ?)
<i>Apus lucasani</i> Packard	2	la	UA ua					Colo., Kan., Lower Calif.
<i>A. aequalis</i> Packard....	1	la	UA ua					Colo., Kan., Texas, Mexico, Lower Calif.



TABLE I.—*Concluded.*

Species.	Number of Lakes	Zones.					Range.
		Lower Austral.	Upper Austral.	Transition.	Canadian.	Hudsonian.	
<i>A. mewberryi</i> Packard..			(UA)				Colo., Utah.
<i>A. longicaudatus</i> Leconte			(UA)				Colo., Neb., Texas, Montana.
<i>Eulimnidia texana</i> Packard.....		?	ua	?			Colo., Neb., Kan., Texas.
<i>Estheria morsei</i> Packard	2		(UA)				S. Dak. to Colo.
			ua				
<i>E. compleximanus</i> Packard .....	1	?	UA				Colo., Kan., Lower Calif.
			ua				
<i>Streptocephalus texanus</i> Packard.....	2		UA				Colo., Neb. to Texas.
		?	ua				
<i>Thamnocephalus platyrus</i> Packard .....	1		UA				Colo., Kansas.
			ua				
<i>Branchinecta packardii</i> Pearse.....	2		UA				Colo.
			ua				
<i>B. lindahli</i> Packard....			UA	t?			Colo., Kan., Neb., Wyoming.
			ua				

counts of localities where each species has been collected. Many of the records are indefinite or very general and do not enable one to judge just what zone is included. The tabulation, in spite of this, contains much of truth and I have attempted to confine its errors to those of omission. The Tropical Zone has been omitted, chiefly because I have been unable to determine certainly which species in my list extend into it. It is likewise difficult to determine which species range into the Arctic-Alpine.

The agreement between the local and general zonal range is striking, and in many cases, complete. The only departures from this agreement are in the cases of certain species for which the local records do not cover as many zones as the general. These species are mostly those which are not abundant and have been met with infrequently in the Colorado collections, such as certain species which are never present in more than very small numbers and may easily be missed in making collections, or others, which though found occasionally in abundance, are met with in only a small proportion of the lakes in the zones which they inhabit. More extensive collections would doubtless extend the records of many of these species to cover other zones and so bring the local records into still closer agreement with the general.

## III. THE FAUNA OF EACH ZONE.

Table II., summarizing the fauna of the different zones, shows the following points of interest. For the species collected in Colorado there is a decrease in number from the Upper Sonoran upward, that is, a thinning out of population as the more extreme conditions of climate are met. An apparent exception is the Transition Zone where the number is less than in the Canadian. This is no doubt due to the fact that in the region assigned to this zone there are very few lakes and the number of collections is accordingly much less than from any other zone. If we add to the number of species actually collected from each zone in Colorado those which from their general distribution are almost certainly to be expected there, the deficiency of the Transition Zone is made up and the general decrease with each successive zone prevails.

TABLE II.

SUMMARY OF RECORDS GIVEN IN TABLE I.

	Upper Austral.	Transi- tion.	Can- adian.	Hud- sonian.	Arctic- Alpine.
Number of species collected in each zone in Colorado . . . . .	44	28	35	23	15
Number of species in the Colorado list to be expected in each zone as determined by comparing local and general records .	52	50	42	34	28
Total number of species collected in Colorado in all zones . . .	71				

*The Upper Sonoran Zone.*

In the Upper Sonoran Zone of this region there occur two kinds of ponds or small lakes: transient pools which follow rains, and ponds and reservoirs filled with water from irrigating ditches. These latter are of recent origin, dating back only to the introduction of agriculture into this region. The fact that they are richly populated speaks well for the effectiveness of the methods of dispersal of plankton Crustacea, but the question may well be raised whether dispersal has kept pace with the increase in number of such bodies of water and whether additions to their fauna may not be expected in future years.

Of the 44 species that have been recorded from this zone in Colorado, 28 have not been found in any of the higher zones,

though nine or more of them occur in the Transition zone of our northern states and may be expected to extend into the local portion of this zone. This leaves 17 species which apparently do not go above the Upper Sonoran, to which must be added some others which have their greatest abundance here rather than in the Transition into which they extend. The remaining species of the zone, roughly half of its population, range upward into other zones, 9 of them as far as the Arctic-Alpine. Thus we recognize among the species of this zone two groups: the one including euthermic species which range upward across temperature lines into the higher zones, the other composed of stenothermic forms, intolerant of great temperature differences and accordingly confined pretty strictly to the zone. The euthermic species, while they form at least half the fauna of the zone, are less likely to receive consideration on account of zonal distribution because they do not form its distinctive part. To this group belong nearly all the species of the family Daphnidæ, many of the Chydoridæ and four of the five species of *Cyclops*, together with a few from other groups.

Conspicuous in the stenothermic component of this zone are two groups: (1) four species of *Diaptomus* and (2) eleven species of phyllopods (Anostraca, Notostraca, and Conchostraca). These two groups are of interest because, not only in this region, but in general they are represented by stenothermic species. *Diaptomus* forms an important part of the entomostracan fauna everywhere and includes many species, nearly all of which are very narrowly stenothermic and have restricted geographic ranges. The phyllopod group is of special interest here, for, though represented in the fauna of all parts of the country, and of the world, forms a more important part here than in most regions. The species of this group are especially abundant in the Sonoran portion of the Austral Zone, where they flourish in the transient pools of this arid region. It will be seen by reference to the last column of Table I., that these species are all of restricted range and confined to the states which include portions of the Sonoran zone. The species of phyllopods, like those of *Diaptomus*, are nearly all stenothermic. The phyllopods belong in greater abundance to the warmer zones, while *Diaptomus* is especially plentiful in the colder ones.

When we search for distinctive faunal characters of the higher zones we are confronted with a problem somewhat different than in the Sonoran. In no other zone is there even a single species confined to it and at the same time abundant enough to be used as a zone indicator. In certain respects the zones of the mountain region, Transition to Arctic-Alpine, form a unit group, which, as a whole, may be contrasted with the Sonoran. There are 23 species which have been collected exclusively in the mountains, many of them in considerable abundance, which clearly belong to the colder zones. Yet when we attempt to apportion them among the zones it is found that most of them range through two or more zones. There are, however, certain pretty definite faunal characters of each zone, a description of which follows.

#### *The Transition Zone.*

In the foothill region of the mountains there are but few lakes or ponds and accordingly few collections have been made and a small number of species recorded from this zone. This leaves some doubt as to the nature of the transition between the fauna of the plains and that of the mountains. We cannot determine whether this is truly a transition zone or if it is one having special and striking characters of its own, though the former view seems more probable. It is further probable that the fauna of this zone partakes more of the nature of the higher than of the lower zones. While there are 23 species which make the Transition Zone their lower limit, there is not one which finds its upper limit in this zone, though from the records of general range, there are some which may be expected to do so when more extensive collections have been made here. Twenty-eight species have been recorded in this zone, but a total of 50 might be expected because certain others of the Colorado list are present in the Transition of our northern states.

#### *The Canadian Zone.*

In the belt assigned to this zone there are many small lakes, nearly all of morainal origin, mostly shallow, often without outlet, and commonly surrounded by forest. Their fauna is rich in individuals and species. There have been collected in the lakes of this zone 37 species, and about 8 others might be expected. This

zone is not one of importance as a limit in either direction, for no such significance can be assigned to the five species from the Upper Sonoran which make this their upper limit or to the three which find their lower limit here. Its fauna does, however, include a number of species in considerable abundance which are common forms in the continental Canadian and other northern zones. Important among these are *Limnetis gouldii*, *Latona setifera*, *Holopedium gibberum*, *Eurycerus lamellatus*, *Acroperus harpæ*, and *Pleuroxus praeurvatus*. Six species of *Diaptomus* common in this zone, *D. shoshone*, *D. coloradensis*, *D. lintoni*, *D. nudus*, *D. judayi*, and *D. leptopus* var. *piscinæ* are confined more or less closely and locally to the higher parts of the Rocky Mountains, where they range through more than one zone.

Of special interest in the Canadian Zone of this region is the great abundance and very frequent association together of *Daphnia longispina* (subject to great local variation) and *Diaptomus leptopus* var. *piscinæ*, which throughout this zone form the dominant species, with *Diaptomus coloradensis* as the form of next importance. *D. longispina*, though a euthermic species and found throughout the world in many varieties, has not been found in Colorado below the Transition and has by far its greatest abundance in the Canadian. *D. leptopus* var. *piscinæ* seems to be confined to the Transition, Canadian, and Hudsonian of the Rocky Mountain region, while *D. coloradensis* is a local species and has not been reported outside the mountain region of the state for which it is named. The list of euthermic species is about the same as in the Upper Sonoran.

#### *The Hudsonian Zone.*

This is a narrow zone, both in vertical and in geographic extent, and has only slight significance. Climatic conditions are more severe than in the Canadian; more snow falls and it lies longer; the summer is shorter and the lakes are colder. In these respects it approaches the Arctic-Alpine. Its lakes are of two sorts: the one of the same type as those common in the Canadian, the other more like those of the Arctic-Alpine—lakes on the direct courses of the creeks like those higher up but differing from them in that they are surrounded by timber and have considerable silt on

their bottoms. Lakes of the former type in this zone have a fauna of much the same nature as in the Canadian, while those of the latter kind have their affinities, though less decidedly so, with the Arctic-Alpine. A few species make this zone their upper limit and it seems probable that it may have some importance in this respect. In the main, it seems to be a transition zone, one having no important distinctive characters and it might well be included within the Canadian.

### *The Arctic-Alpine Zone.*

This zone is an interesting one partly because of a type not familiar to us, and partly because its fauna is distinctive and striking. The lakes of this zone lie in the deep cirques at the heads of the streams and on the stream courses not far below, and are all just at or above timberline. Most of them are deep and clean and are bordered by steep, rocky slopes. Ice remains till June or July or even later, and the snowdrifts on the surrounding walls furnish cold water throughout the greater part of the summer so that the highest temperatures reached range from 45° to 55° F. Shallow pools of this region have about the same type of fauna and must clearly be classed along with the lakes of this zone.

Fifteen species have been collected here, nine of which are widely euthermic and range through all the zones, not only to the Upper Sonoran of Colorado, but into the Lower Sonoran and Austral, and in some cases into the Tropical. Nearly all of the more abundant species of the zone belong to this group, as *Daphnia pulex*, *Chydorus sphaericus*, *Alona rectangula*, and four species of *Cyclops*. Species of more restricted zonal range are, however, important and abundant, though none of great importance is confined to the zone. Most of the northern species listed as of importance in the Canadian fail to reach this zone, but find their highest range in the Hudsonian, though it appears from records of their presence in Greenland and other high northern regions that they might be expected here. An abundance of collections in this region has not, however, found them in the Arctic-Alpine of this region, and we must omit them from its list.

The two most conspicuous and abundant species are *Diaptomus*

*shoshone* (33 lakes out of 43) and *Daphnia pulex* (27 lakes). One or both of these species were found in 39 of 43 lakes in this zone. *Diaptomus shoshone* is a large and brilliantly colored species, was described by Forbes from the Yellowstone, and has been reported only from that region and high portions of the Rockies in Colorado. It ranges into lakes far within the Canadian Zone, but has by far its greatest abundance in the lakes and pools above timberline. *Daphnia pulex* is a cosmopolitan and euthermic form but is much more abundant in these high lakes than in any other part of the mountains, in fact is nearly wanting from the Hudsonian and Canadian, where it is replaced by *Daphnia longispina* just as *Diaptomus shoshone* is replaced by *D. leptopus* var. *piscinæ*. The variety of *Daphnia pulex* found in these lakes is unusually large, and though subject to considerable local variation, comes close to the form described from the Yellowstone as *D. clathrata* by Forbes, where, too, it is associated with *D. shoshone*. One of the striking and outstanding features about zonal distribution in this region is this definite and constant association of a species of *Daphnia* with one of *Diaptomus*. The two combinations are striking and constant, one belongs definitely to the Canadian, the other to the Arctic-Alpine, and the reverse combination is seldom met. Neither member of the Canadian pair has been collected from lakes in the Arctic-Alpine, and though both members of the alpine pair do sometimes invade the Canadian, they usually go together and are found in lakes where the other pair is wanting. *Diaptomus coloradensis* is frequently found in the Arctic-Alpine but is of secondary importance just as in the Canadian.

Another species of importance in this zone is the fairy shrimp, *Branchinecta coloradensis* which is commonly found in the pools, though never in the lakes, along with *Daphnia pulex* and *Diaptomus shoshone*. This species was described by Packard from an elevation of 12,000 feet on Gray's Peak, has been repeatedly found in these high pools, and has come to stand as a type of a distinctly alpine species of narrow range (Shantz, '05). Only once have I collected it below the Arctic-Alpine, this at 9,575 feet, well within the Canadian Zone, and there it was associated with the same species of *Daphnia* and *Diaptomus* as in the higher

regions. I have one record, however, from a collection dated May 30, 1912, sent me by Professor Max M. Ellis from St. Vrain, Colorado, at an elevation of about 5,100 feet and well within the Upper Sonoran. It seems improbable that there can be any mistake about the label of this collection, and I have repeatedly looked at the material in an attempt to detect differences which would relieve me of the necessity of referring it to this species. This record places it at once in the Upper Sonoran and calls for a revision of our notions of its distribution.

#### IV. SUMMARY AND DISCUSSION.

The zonal distribution, local and general, of the 71 species included in this report affords good material for the study of certain characteristics of euthermic and stenothermic species belonging to closely related families and genera. It is at once apparent that the total entomostracan population of this region is readily divisible into these two components. The euthermic species not only range through several zones in their local and general distribution, but a large proportion of them are essentially cosmopolitan, being reported from all parts of the world where collections have been made. The stenothermic species are divisible into two groups, one belonging to the colder, the other to the warmer zones. The stenothermic species of the colder zones may in turn be resolved into two groups, one of which includes species that range over a considerable area from Colorado northward into the corresponding zones of our northern states, Canada, and even into Greenland, Iceland, and northern Europe, while the other includes species with very narrow ranges, confined to the higher parts of the Rocky mountains. The stenothermic species of the warmer lakes (the Upper Sonoran of Colorado) may likewise be divided into two groups, one, of species ranging over the Sonoran, and through the Austral in general, and into the Tropical Zone, the other, of those with a narrow range in the Upper Sonoran of a few states.

It is further evident from a scrutiny of the facts presented in Table I., where the species are arranged on the basis of temperature toleration, that such a grouping bears a certain relation to taxonomic groups, inasmuch as some of these groups are



largely stenothermic and others euthermic. The outstanding features as seen in the Colorado list are as follows:

The 16 species of phyllopods in the list are, with two exceptions, narrowly stenothermic and all but one of the stenothermic species belong to the warm-climate fauna. It is moreover true that nearly all of the known species of the group are stenothermic and have narrow geographic ranges. Among the Cladocera, the Family Daphnidæ is represented by 11 species which are nearly all euthermic in a broad sense, are found at all elevations and in all zones, and are decidedly cosmopolitan, while the Chydoridæ has 16 species about equally divided between stenothermic and euthermic types. The Copepods include two sharply contrasted genera, *Cyclops* and *Diaptomus*, both of which form important components of the entomostracan fauna in all parts of the world. *Diaptomus* has 13 species in the Colorado list, not one of which is euthermic in any broad sense, and all of which are confined within areas of very limited extent. *Cyclops*, on the other hand, with only 5 species, is fully as important. Three of these are broadly cosmopolitan and euthermic, a fourth (*C. bicuspidatus*) is nearly so, being absent only from the warmer waters, and the fifth (*C. ater*), confined to the United States and not found north of the Transition Zone, has as great a range as the widest spread species of *Diaptomus*.

I believe the collections of Entomostraca described in this paper are the most extensive that have been made in this country from a region where high mountains cause such a decided narrowing of life zones. So far as I know, this is also the first attempt to define the entomostracan fauna of the various zones of such an area and to definitely place them with reference to Merriam's Life Zones. The data from Colorado lend themselves well to such an analysis. The zonation is definite, even though the present collections do not enable us to discriminate between all of the colder zones. It is equally difficult, on the basis of our present knowledge, to sharply differentiate these same zones in their continental extent in Canada and northern United States.

Yet it seems well established by these data that the entomostracan population of the various life zones as they occur in the mountains of Colorado are but attenuated southern extensions

and isolated fragments of the broader life zones, from Transition to Arctic-Alpine, which extend from east to west across the continent. Though these zones have been established and defined on the basis of organisms other than entomostraca, yet the agreement is striking and real and extends even to common species inhabiting the same zones in localities hundreds of miles apart and separated by many degrees of latitude.

In this fact we are brought again to a recognition of the truth that change in elevation may, within a very few miles, produce climatic and biotic differences which are brought about by latitude, only after hundreds of miles. It shows clearly that life zones are neither latitudinal, nor altitudinal, though these are the two large factors which interact to produce them. We have not discovered an exact mathematical formula for determining life zones on the basis of these two factors, nor are we able to accurately define them on the basis of climatic conditions, but they may be defined and compared in terms of distribution of animals and plants. These, of course, serve as a measure of climatic conditions, that is, as these conditions determine the distribution of the several species. It is apparently not the case that temperature acts in exactly the same way on all species of animals and plants in determining their distribution. For some, it is apparently winter conditions which limit their range into colder regions, though for the great mass, it is probably summer conditions. It is not the purpose of this paper to enter into a discussion of this point, though the fact of winter-killing of certain species is well known, while it is recognized also that every species requires a certain minimum heat budget during the summer, extending over a longer or shorter period, in order that it may reproduce.

It is not to be expected that limiting lines for all species will be exactly parallel, yet there is a large agreement, so that the zones do, in a high degree, maintain their several identities in whatever proportions altitude and latitude interact in producing them. It would be of interest to investigate further into the extent and nature of this identity between the colder zones of the elevated parts of Colorado and the less elevated portions of these zones in the far north. The present study goes merely far enough

to demonstrate an agreement of a general nature without showing in detail its extent.

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